WHAT IS CLAIMED IS:

1. A method for efficiently transferring a spacecraft to a desired orbit, the method comprising:

computing a continuous-firing thrust trajectory to achieve an orbit transfer;

computing thrust effectiveness values for time intervals over the continuous-firing thrust trajectory;

comparing the thrust effectiveness values with a thrust effectiveness threshold value; and

computing an intermittent-firing thrust trajectory to achieve the orbit transfer, the intermittent-firing thrust trajectory comprising thruster-on regions where the thrust effectiveness value is about or above the thrust effectiveness threshold value, and thruster-off regions where the thrust effectiveness value is below the thrust effectiveness threshold value.

2. The method as recited in claim 1, wherein computing the intermittent-firing thrust trajectory comprises:

determining one or more thruster-off regions for a first orbit revolution;

computing a first updated thrust trajectory for the entire orbit transfer using the thruster-off regions identified for the first orbit revolution in the calculation;

determining one or more thruster-off regions for a second orbit revolution using the first updated trajectory;

computing a second updated thrust trajectory for the entire orbit transfer using the thruster-off regions identified for the first and the second orbit revolutions in the calculation; and

continue computing thruster-off regions for each successive orbit revolution and further updated thrust trajectories until a final intermittent-firing thrust trajectory is determined for all orbits of the entire orbit transfer.

3. The method as recited in claim 2, wherein the thruster-on regions, the thruster-off regions and the final intermittent-firing thrust trajectory are determined prior to carrying out the orbit transfer.

4. The method as recited in claim 1, wherein the thrust effectiveness value is calculated according to the equation:

$$\Gamma(t) = 1 - \frac{\lambda_6 \dot{F}}{\lambda^T \dot{z}}$$

5. The method as recited in claim 1, wherein prior to comparing the thrust effectiveness value with a thrust effectiveness threshold value, the method further comprises determining the thrust effectiveness threshold value.

6. The method as recited in claim 5, wherein the thrust effectiveness threshold value is a function of thruster shut-off time, fuel savings and increase in orbit transfer time.

7. The method as recited in claim 5, wherein the thrust effectiveness threshold value is denoted Γ_0 and can be solved for by evaluating the integrals

$$T_1(\Gamma_0) = \int_0^T \eta \Gamma dt \qquad \text{where,} \qquad \eta = 1 \quad \text{if } \Gamma \leq \Gamma_0$$
$$T_2(\Gamma_0) = \int_0^T \eta\, (1 - \Gamma) dt \qquad\qquad \eta = 0 \quad \text{if } \Gamma > \Gamma_0$$

for values of Γ_0 between 0 and 1 with a reasonable resolution, wherein T_1 gives a relationship between the thrust effectiveness threshold value Γ_0 and a total increase in the orbit transfer time, and wherein T_2 gives a relationship between the thrust effectiveness threshold value Γ_0 and a reduction in firing time.

8. The method as recited in claim 1, wherein an amount of fuel required to perform the orbit transfer is lower than the amount of fuel required to perform a time-optimal continuous-firing orbit transfer.

9. The method as recited in claim 1, wherein an increase in transfer time compared to a time-optimal continuous firing orbit transfer is minimized.

10. The method as recited in claim 1, wherein the thrusters are not fired when the orbit change is insensitive to thrusting.

11. The method as recited in claim 1, wherein the thrusters are not fired when a required rate of change of thrust trajectory direction is too large for the spacecraft to follow.

12. The method as recited in claim 1, wherein the change in orbit comprises a transfer from a launch vehicle injection orbit to a final mission orbit.

13. The method as recited in claim 1, wherein the thrusters are not fired when continuously firing the thrusters will not reduce the velocity change required to complete the orbit transfer by at least a threshold amount.

14. A spacecraft orbit transfer system adapted to transfer the spacecraft from a first orbit to a second orbit, the system comprising:

spacecraft thrusters; and

at least one controller adapted to control the spacecraft orbit transfer;

the spacecraft orbit transfer system being adapted to:

compute a continuous-firing thrust trajectory to achieve an entire orbit transfer;

compute thrust effectiveness values for time intervals over the continuous-firing thrust trajectory;

compare the thrust effectiveness values with a thrust effectiveness threshold value; and

compute an intermittent-firing thrust trajectory to achieve the orbit transfer, the intermittent-firing thrust trajectory comprising thruster-on regions where the thrust effectiveness value is at about or above the thrust effectiveness threshold value and thruster-off regions where the thrust effectiveness value is below the thrust effectiveness threshold value, wherein the spacecraft thrusters are turned-on during the thruster-on regions, and the spacecraft thrusters are turned-off during the thruster-off regions.

15. The system as recited in claim 14, wherein the at least one controller is selected from the group consisting of at least one controller on the spacecraft, at least one controller on the earth, and a combination of at least controller on the spacecraft and at least one controller on the earth.

16. The system as recited in claim 14, wherein the spacecraft orbit transfer system computes the intermittent-firing thrust trajectory by:

determining one or more thruster-off regions for a first orbit revolution;

computing a first updated thrust trajectory for the entire orbit transfer using the thruster-off regions identified for the first orbit revolution in the calculation;

determining one or more thruster-off regions for a second orbit revolution using the first updated trajectory;

computing a second updated thrust trajectory for the entire orbit transfer using the thruster-off regions identified for the first and the second orbit revolutions in the calculation; and

continue computing thruster-off regions for each successive orbit revolution and further updated thrust trajectories until a final intermittent-firing thrust trajectory is determined for all orbits of the entire orbit transfer.

17. The system as recited in claim 16, wherein the spacecraft orbit transfer system determines the thruster-on regions, the thruster-off regions and the final intermittent-firing thrust trajectory prior to carrying out the orbit transfer.

18. The system as recited in claim 14, wherein the thrust effectiveness value is calculated according to the equation:

$$\Gamma(t) = 1 - \frac{\lambda_6 \dot{F}}{\lambda^T \dot{z}}$$

19. The system as recited in claim 14, wherein the spacecraft orbit transfer system determines the thrust effectiveness threshold value prior to comparing the thrust effectiveness value with a thrust effectiveness threshold value.

20. The system as recited in claim 19, wherein the thrust effectiveness threshold value is a function of thruster shut-off time, fuel savings and increase in orbit transfer time.

21. The system as recited in claim 19, wherein the thrust effectiveness threshold value is denoted Γ_0 and can be solved for by evaluating the integrals

$$T_1(\Gamma_0) = \int_0^T \eta \Gamma dt \qquad \text{where,} \qquad \eta = 1 \quad \text{if } \Gamma \le \Gamma_0$$
$$T_2(\Gamma_0) = \int_0^T \eta \, (1-\Gamma) dt \qquad \qquad \eta = 0 \quad \text{if } \Gamma > \Gamma_0$$

for values of Γ_0 between 0 and 1 with a reasonable resolution, wherein T_1 gives a relationship between the thrust effectiveness threshold value Γ_0 and a total increase in the orbit transfer time, and wherein T_2 gives a relationship between the thrust effectiveness threshold value Γ_0 and a reduction in firing time.

22. The system as recited in claim 14, wherein an amount of fuel required to perform the orbit transfer is lower than the amount of fuel required to perform a time-optimal continuous-firing orbit transfer.

23. The system as recited in claim 14, wherein an increase in transfer time compared to a time-optimal continuous firing orbit transfer is minimized.

24. The system as recited in claim 14, wherein the thrusters are not fired when the spacecraft orbit change is insensitive to thrusting.

25. The system as recited in claim 14, wherein the thrusters are not fired when a required rate of change of thrust trajectory direction is too large for the spacecraft to follow.

26. The system as recited in claim 14, wherein the first orbit comprises a launch vehicle injection orbit and the second orbit comprises a final mission orbit.

27. The system as recited in claim 14, wherein the thrusters are not fired when continuously firing the thrusters will not reduce the velocity change required to complete the orbit transfer by at least a threshold amount.

28. A spacecraft adapted to transfer from a first orbit to a second orbit, comprising:

spacecraft thrusters; and

an orbit transfer system adapted to transfer the spacecraft from a first orbit to a second orbit, the orbit transfer system comprising at least one controller adapted to control the spacecraft orbit transfer, the spacecraft orbit transfer system being adapted to:

compute a continuous-firing thrust trajectory to achieve an entire orbit transfer;

compute thrust effectiveness values for time intervals over the continuous-firing thrust trajectory;

compare the thrust effectiveness values with a thrust effectiveness threshold value; and

compute an intermittent-firing thrust trajectory to achieve the orbit transfer, the intermittent-firing thrust trajectory comprising thruster-on regions where the thrust effectiveness value is at about or above the thrust effectiveness threshold value and thruster-off regions where the thrust effectiveness value is below the thrust effectiveness threshold value, wherein the spacecraft thrusters are turned-on during the thruster-on regions, and the spacecraft thrusters are turned-off during the thruster-off regions.

29. The spacecraft as recited in claim 28, wherein the at least one controller is selected from the group consisting of at least one controller on the spacecraft, at least one controller on the earth, and a combination of at least controller on the spacecraft and at least one controller on the earth.

30. The spacecraft as recited in claim 28, wherein the orbit transfer system computes the intermittent-firing thrust trajectory by:

determining one or more thruster-off regions for a first orbit revolution;

computing a first updated thrust trajectory for the entire orbit transfer using the thruster-off regions identified for the first orbit revolution in the calculation;

determining one or more thruster-off regions for a second orbit revolution using the first updated trajectory;

computing a second updated thrust trajectory for the entire orbit transfer using the thruster-off regions identified for the first and the second orbit revolutions in the calculation; and

continue computing thruster-off regions for each successive orbit revolution and further updated thrust trajectories until a final intermittent-firing thrust trajectory is determined for all orbits of the entire orbit transfer.

31. A method for transferring a spacecraft from a first orbit to a second orbit, comprising:

calculating thruster-off regions within the orbit transfer in which it is efficient to turn-off spacecraft thrusters; and

turning off the spacecraft thrusters in the thruster-off regions.